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Colorado River Basin Regional Water Quality Control Board

June 6, 2018

Mr. Bruce Wilcox, Assistant Secretary for Salton Sea Policy
Salton Sea Science Advisory Committee
California Natural Resources Agency
78078 Country Club Drive, Suite 109
Bermuda Dunes, CA 92203

Dear Mr. Wilcox:

SUBJECT: PRELIMINARY EVALUATION OF SEA-TO-SEA TRANSFER VOLUMES

This letter has been prepared to summarize a preliminary evaluation of the volume of water involved in a "sea-to-sea transfer" mitigation strategy, where ocean water is imported into the Salton Sea to maintain elevation, and Salton Sea water is exported to the ocean to control salinity. Estimating the quantity of water needed to meet the goals of the sea-to-sea transfer is critical in evaluating the feasibility of this mitigation strategy. This evaluation was performed by preparing a spreadsheet that considers the most important variables that affect the quantity of water needed, and generates a graph of the quantity of water needed for different water inflow scenarios.

Assumptions

This evaluation assumes the goals of the sea-to-sea transfer are to:

1. Raise and maintain the Salton Sea surface elevation to a fixed historic level, so that the marinas and beaches along the shorelines can continue to be used;
2. Reduce and maintain the salinity of the Salton Sea to a value tolerable for wildlife;
3. Accommodate decreasing volumes of Colorado River and/or farm water runoff (collectively referred to as river water) by importing ocean water, as needed.

Method

The spreadsheet uses a salt-balance approach to evaluate the quantity of water involved in a sea-to-sea transfer that meets the goals listed above. Variables consist of:

1. Target Salton Sea surface area associated with the target elevation, in acres;
2. Evaporation rate, in feet per year;
3. Ocean salinity, in mg/L
4. River water salinity, in mg/L;
5. The volume of river water reaching the Salton Sea, in acre-feet (AF);
6. Target salinity to be maintained in the Salton Sea, in mg/L.

The spreadsheet works using the following steps:

1. The quantity of water needed to maintain the sea at the target elevation is calculated by multiplying the target surface area at that elevation (variable 1) and the evaporation rate (variable 2).
2. The quantity of imported ocean water needed to maintain the target surface elevation is equal to the evaporated volume (from step 1) minus the river water volume (variable 5).
3. The quantity of salt associated with elevation control is equal to the salt load in the river water (variable 4) plus the salt load in the ocean water imported for elevation control (variable 3 times the quantity derived in step 2).
4. The rate at which salt is removed by a sea-to-sea transfer method is equal to the difference in salinity between ocean water (variable 3) and the target Salton Sea salinity (variable 6). That difference is calculated by subtracting the ocean salinity (variable 3) from the target salinity (variable 6). Basically, for every AF of Salton Sea water removed, an AF of ocean water has to be imported to take its place, so only the difference in salinity is being removed. This difference is relatively small.
5. The volume of Salton Sea water and ocean water to be exchanged to maintain salinity is equal to the quantity of salt being imported for elevation control (step 3) divided by the difference in salinity between the ocean and the Salton Sea (step 4).
6. The total volume of ocean water to be imported is equal to the volume needed for elevation control (step 2) AND the volume needed for salinity control (step 5).
7. The total volume of Salton Sea water to be exported is equal to the volume needed for salinity control (step 5).

Equations

For those readers who prefer equations:

$$\text{Ocean import for elevation control} = (\text{Area} \times \text{Evaporation}) - V_{river}$$

$$\text{Salton Sea export for salinity control} = \frac{((\text{Area} \times \text{Evap} - V_{river}) \times \text{Salinity}_{ocean}) + (V_{river} \times \text{Salinity}_{river})}{(\text{Salton Sea Salinity} - \text{Ocean Salinity})}$$

$$\text{Total Ocean import} = \text{Ocean import for elevation} + \text{Salton Sea export for salinity control}$$

Where:

V_{river} is the volume of the river water reaching the Salton Sea in AF per year;
Area is the area of the stabilized Salton Sea, in acres;
Evaporation and Evap are the annual net evaporation rate of the Salton Sea, in feet per year;
Salinity_{ocean} is the salinity of the ocean, in mg/L;
Salinity_{river} is the salinity of the river water reaching the Salton Sea, in mg/L; and
All calculated volumes are in AF per year

Discussion

Several graphs were created to show the sea-to-sea transfer volumes for a range of river water volumes using a range of evaporation rates. The sea-to-sea transfer volume increases as the quantity of river water decreases. The quantity of the sea-to-sea transfer is also quite sensitive to the evaporation rate and the salinity of the river water.

As shown in Graphs 1, 2 and 3, the ocean water inflow always exceeds the Salton Sea outflow volume. At a river water volume of 850,000 AF/yr, the volume of ocean water needed to maintain the Salton Sea elevation and salinity, and the volume of Salton Sea water needing to be exported are approximately as follows for the three evaporation rates:

Evaporation Rate	Ocean Import	Salton Sea Export
6.0 ft/yr	2,700,000 AF/yr	2,200,000 AF/yr
6.5 ft/yr	3,200,000 AF/yr	2,600,000 AF/yr
7.0 ft/yr	3,700,000 AF/yr	3,000,000 AF/yr

These values are large, and indicate the scale needed to successfully use sea-to-sea transfer to maintain both the elevation and salinity of the Salton Sea. Copies of the spreadsheet printouts for the evaporate rates are enclosed.

Additional Considerations

In addition to the salt balance approach discussed above, the spreadsheet was also used to estimate several other issues:

1. The total volume of the Salton Sea, assuming an average depth of 35 feet; and

2. If evaporation basins were used to control the salinity, the area needed to evaporate the salt load received from only the river water.

These are useful for comparison purposes and indicate:

A. Assuming an average depth of 35 feet over an area of 230,000 acres, the total volume of the Salton Sea is about 8,000,000 AF. In this case, the sea-to-sea transfer would exchange about 50 to 100 percent of the volume of the Salton Sea every year, depending on the variables used, and would exceed the volume of the Salton Sea at an evaporation rate of 7 feet per year if the river water volume drops to 650,000 AF per year.

B. For a river water volume of 850,000 AF, the volume of Salton Sea water to be exported to maintain salinity (due exclusively to river water) ranges from about 70,000 AF/yr (for a river salinity of 3,500 mg/L) to 100,000 AF/yr (for a river salinity of 5,000 mg/L).

C. Using evaporation basins filled with Salton Sea water to maintain the salinity due exclusively to 850,000 AF per year of river water salinity requires between 14 square miles at an evaporation rate of 7 ft/yr and a river salinity of 3,500 mg/L, to 25 square miles at an evaporation rate of 6 ft/yr and a river salinity of 5,000 mg/L. These basins would eventually fill with salt.

Items B and C only address the salinity of the river water, and neither would maintain the elevation of the Salton Sea, which would slowly decline until the smaller surface area matches the area sustainable by the river water inflow volume.

Limitations

Note that this evaluation is intended to provide an estimate of the amount of water required to be imported and exported to achieve the goals of the sea-to-sea transfer, and is not intended to be a policy analysis. The evaluation is applicable to stable conditions after the salinity of the Salton Sea has reached its target concentration, and does not evaluate the time it would take to reach that goal. The evaluation does not rigorously examine all of the variables. Given the preliminary nature of this evaluation, and the variability of the rainfall and river water reaching the Salton Sea, refining the evaluation to include more variables is probably not warranted at this time.

If you have questions regarding this document, email scot.stormo@waterboards.ca.gov or call me at (760) 776-8964.

Sincerely,

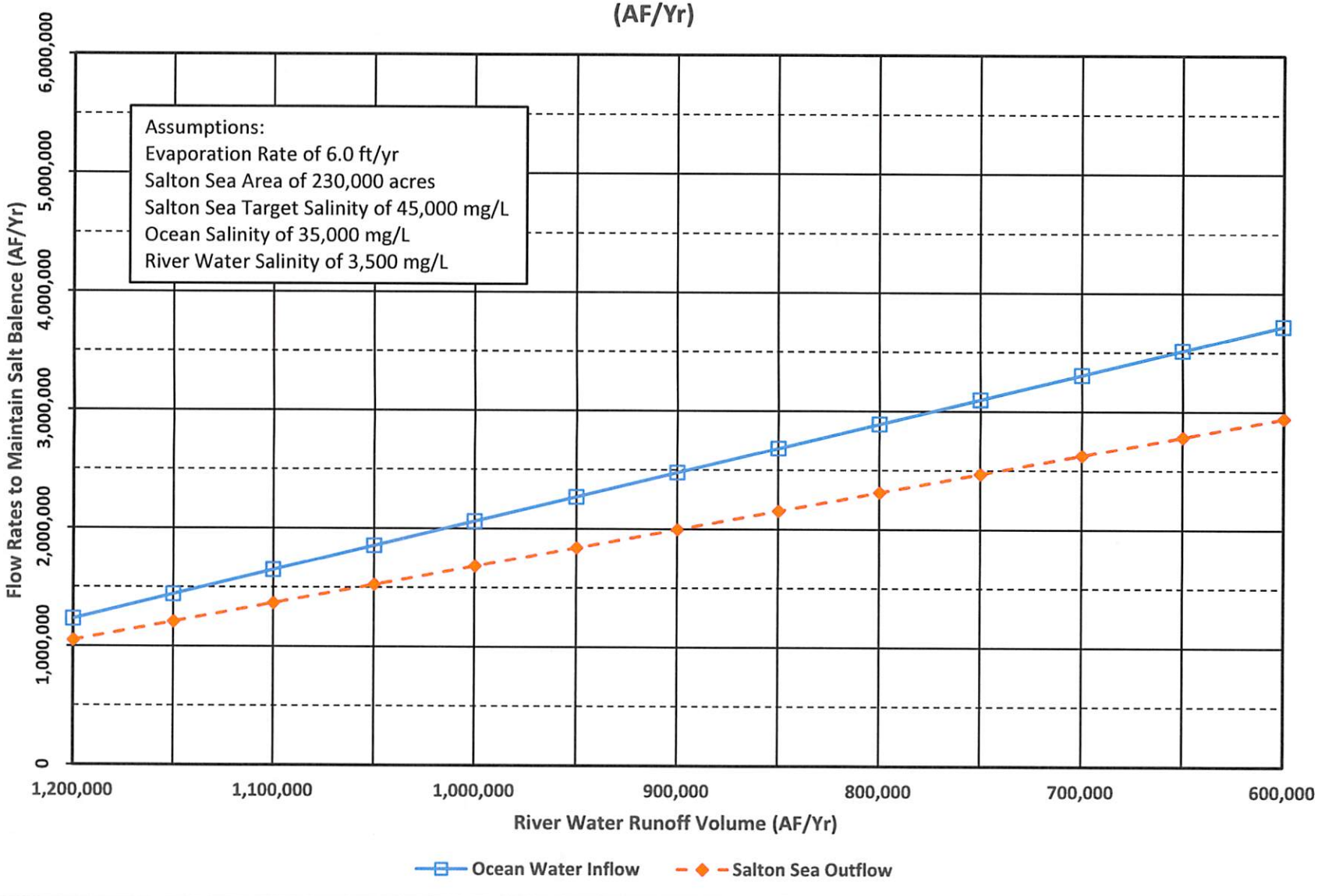
Scot Stormo, PG, CHG
Engineering Geologist
Colorado River Basin
Regional Water Quality Control Board

SS/tab

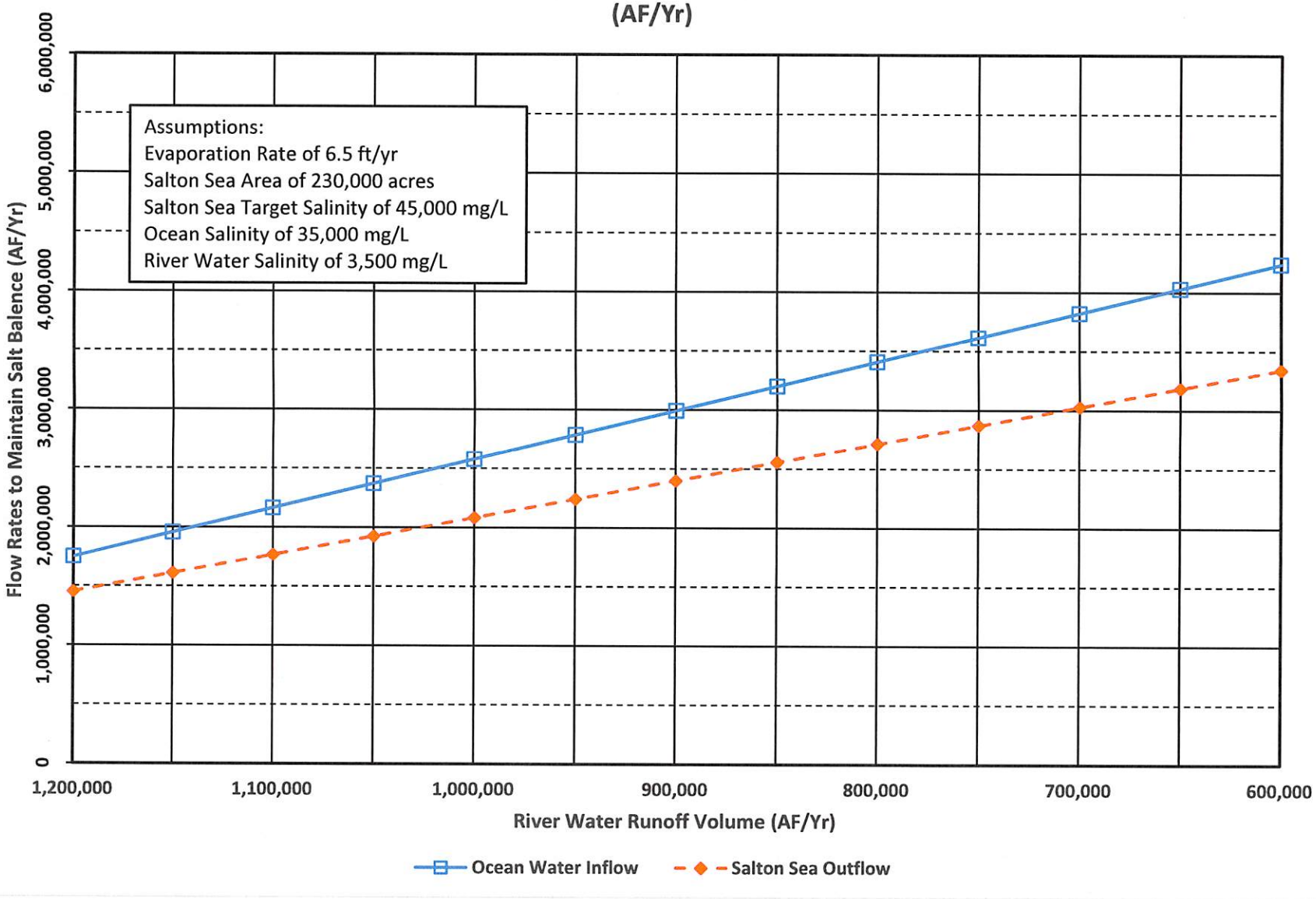
Enclosures: Graphs 1, 2, and 3
Spreadsheet printouts associated with the graphs

cc: Carol A. Roberts, Science Advisory Committee Chair, Carol_a_roberts@fws.gov

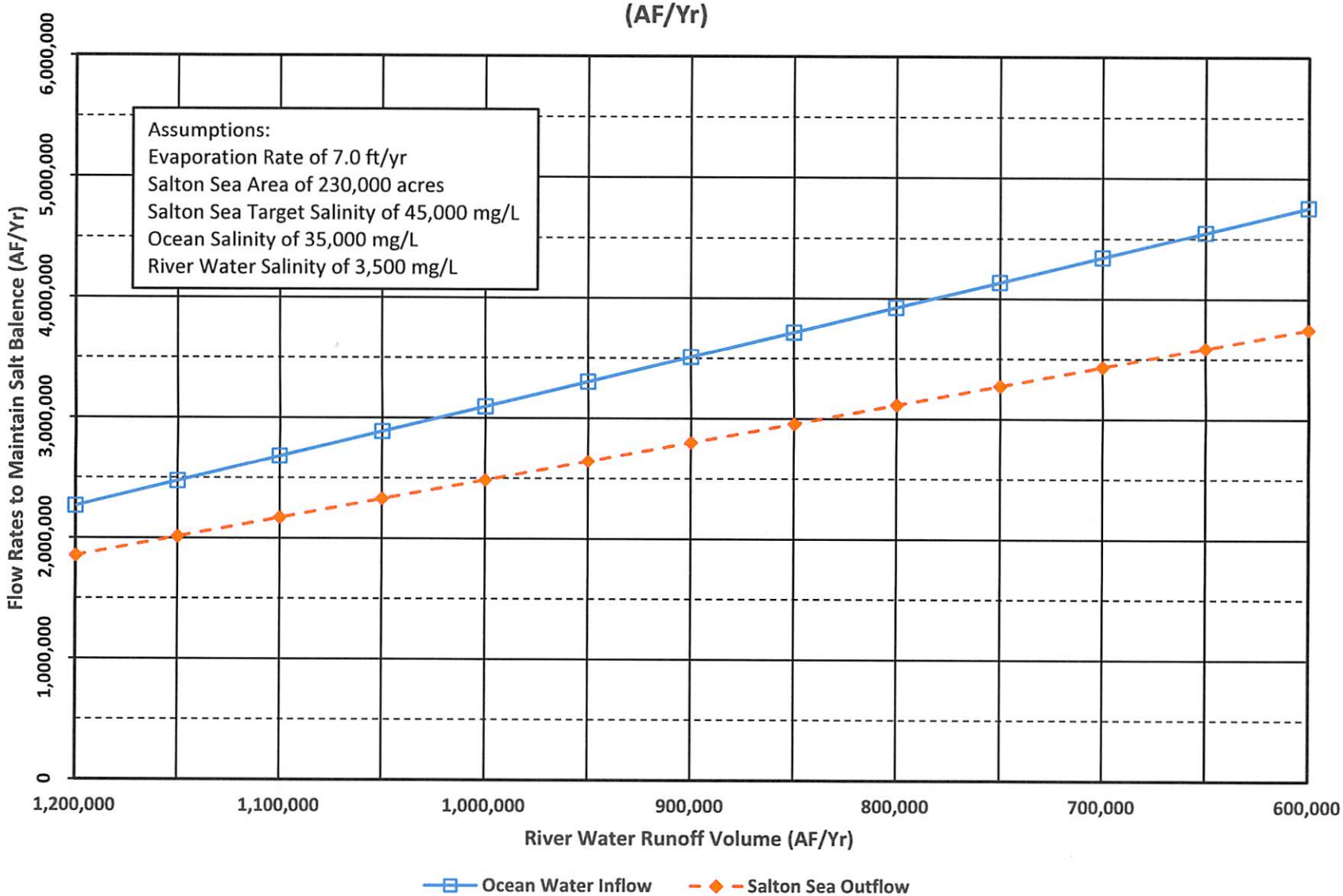
Graph 1: Water Exchange between Ocean and Salton Sea to Maintain Salt Balance with a Full Salton Sea (AF/Yr)



Graph 2: Water Exchange between Ocean and Salton Sea to Maintain Salt Balance with a Full Salton Sea (AF/Yr)



Graph 3: Water Exchange between Ocean and Salton Sea to Maintain Salt Balance with a Full Salton Sea (AF/Yr)



Salt Balance Evaluation for Sea-to-Sea Transfer Scenarios

By Scot Stormo, RWQCB

Variables Yellow highlighting are the variables. Non-highlighted cells are calculated.

Stabilized Salton Sea Area (Acres)	Evaporation Rate (feet/yr)	Evaporative Losses (AF/yr)	Ocean Salinity (mg/L TDS)	River Water Salinity (mg/L TDS)	Target Salinity For The Salton Sea	Difference between Salton Sea and Ocean	
230000	6	1380000	35000	3500	45000	10000	mg/L
	72	<=(inches per year)	43.17	4.32	55.51	12.33	Tonnes/AF

Conversion Factors
1233482 Liters/AF
0.00123348 mg/L to Tonnes/AF

Average Depth of the Salton Sea (ft)	Surface Area of the Salton Sea (acres)	Volume of the Salton Sea (AF)
35	230,000	8,050,000

Sea-to-Sea Evaluation

Volume of River Inflow	Sum of Ocean Input (AF/Yr)	Sum of Salton Sea Output (AF/Yr)	Ocean Input for Stability (AF)	Salt Load Rivers (tonnes)	Salt Load Ocean Stability (tonnes)	Total Salt Input (Tonnes)	Ocean/Salton Sea Exchange for salt balance (AF)
1200000	1230000	1050000	180000	5180624	7770937	12951561	1050000
1150000	1437500	1207500	230000	4964765	9929530	14894295	1207500
1100000	1645000	1365000	280000	4748906	12088124	16837029	1365000
1050000	1852500	1522500	330000	4533046	14246717	18779763	1522500
1000000	2060000	1680000	380000	4317187	16405311	20722498	1680000
950000	2267500	1837500	430000	4101328	18563904	22665232	1837500
900000	2475000	1995000	480000	3885468	20722498	24607966	1995000
850000	2682500	2152500	530000	3669609	22881091	26550700	2152500
800000	2890000	2310000	580000	3453750	25039685	28493434	2310000
750000	3097500	2467500	630000	3237890	27198278	30436168	2467500
700000	3305000	2625000	680000	3022031	29356872	32378903	2625000
650000	3512500	2782500	730000	2806172	31515465	34321637	2782500
600000	3720000	2940000	780000	2590312	33674059	36264371	2940000
550000	3927500	3097500	830000	2374453	35832652	38207105	3097500

Salt Balance for River by Evaporation Only	Salt in River Water Runoff	Salton Sea equivalents	Evap rate AF/mi^2	Area Needed to Remove Salt Assoc with River Water Using Salton Sea Evaporation	
River Inflow Volume	tonnes	AF	AF	Square Miles	Acres
1,200,000	5,180,624	93,333	3,840	24.31	15556
1,150,000	4,964,765	89,444	3,840	23.29	14907
1,100,000	4,748,906	85,556	3,840	22.28	14259
1,050,000	4,533,046	81,667	3,840	21.27	13611
1,000,000	4,317,187	77,778	3,840	20.25	12963
950,000	4,101,328	73,889	3,840	19.24	12315
900,000	3,885,468	70,000	3,840	18.23	11667
850,000	3,669,609	66,111	3,840	17.22	11019
800,000	3,453,750	62,222	3,840	16.20	10370
750,000	3,237,890	58,333	3,840	15.19	9722
700,000	3,022,031	54,444	3,840	14.18	9074
650,000	2,806,172	50,556	3,840	13.17	8426
600,000	2,590,312	46,667	3,840	12.15	7778
550,000	2,374,453	42,778	3,840	11.14	7130

Salt Balance Evaluation for Sea-to-Sea Transfer Scenarios

By Scot Stormo, RWQCB

Variables Yellow highlighting are the variables. Non-highlighted cells are calculated.

Stabilized Salton Sea Area (Acres)	Evaporation Rate (feet/yr)	Evaporative Losses (AF/yr)	Ocean Salinity (mg/L TDS)	River Water Salinity (mg/L TDS)	Target Salinity For The Salton Sea	Difference between Salton Sea and Ocean	
230000	6.5	1495000	35000	3500	45000	10000	mg/L
	78	<=(inches per year)	43.17	4.32	55.51	12.33	Tonnes/AF

Conversion Factors
1233482 Liters/AF
0.00123348 mg/L to Tonnes/AF

Average Depth of the Salton Sea (ft)	Surface Area of the Salton Sea (acres)	Volume of the Salton Sea (AF)
35	230,000	8,050,000

Sea-to-Sea Evaluation

Volume of River Inflow	Sum of Ocean Input (AF/Yr)	Sum of Salton Sea Output (AF/Yr)	Ocean Input for Stability (AF)	Salt Load Rivers (tonnes)	Salt Load Ocean Stability (tonnes)	Total Salt Input (Tonnes)	Ocean/Salton Sea Exchange for salt balance (AF)
1200000	1747500	1452500	295000	5180624	12735702	17916326	1452500
1150000	1955000	1610000	345000	4964765	14894295	19859060	1610000
1100000	2162500	1767500	395000	4748906	17052889	21801794	1767500
1050000	2370000	1925000	445000	4533046	19211482	23744529	1925000
1000000	2577500	2082500	495000	4317187	21370076	25687263	2082500
950000	2785000	2240000	545000	4101328	23528669	27629997	2240000
900000	2992500	2397500	595000	3885468	25687263	29572731	2397500
850000	3200000	2555000	645000	3669609	27845856	31515465	2555000
800000	3407500	2712500	695000	3453750	30004450	33458199	2712500
750000	3615000	2870000	745000	3237890	32163043	35400933	2870000
700000	3822500	3027500	795000	3022031	34321637	37343668	3027500
650000	4030000	3185000	845000	2806172	36480230	39286402	3185000
600000	4237500	3342500	895000	2590312	38638824	41229136	3342500
550000	4445000	3500000	945000	2374453	40797417	43171870	3500000

Salt Balance for River by Evaporation Only

River Inflow Volume	Salt in River Water Runoff tonnes	Salton Sea equivalents AF	Evap rate AF/mi^2 AF	Area Needed to Remove Salt Assoc with River Water Using Salton Sea Evaporation Square Miles	Acres
1,200,000	5,180,624	93,333	4,160	22.44	14359
1,150,000	4,964,765	89,444	4,160	21.50	13761
1,100,000	4,748,906	85,556	4,160	20.57	13162
1,050,000	4,533,046	81,667	4,160	19.63	12564
1,000,000	4,317,187	77,778	4,160	18.70	11966
950,000	4,101,328	73,889	4,160	17.76	11368
900,000	3,885,468	70,000	4,160	16.83	10769
850,000	3,669,609	66,111	4,160	15.89	10171
800,000	3,453,750	62,222	4,160	14.96	9573
750,000	3,237,890	58,333	4,160	14.02	8974
700,000	3,022,031	54,444	4,160	13.09	8376
650,000	2,806,172	50,556	4,160	12.15	7778
600,000	2,590,312	46,667	4,160	11.22	7179
550,000	2,374,453	42,778	4,160	10.28	6581

Salt Balance Evaluation for Sea-to-Sea Transfer Scenarios

By Scot Stormo, RWQCB

Variables Yellow highlighting are the variables. Non-highlighted cells are calculated.

Stabilized Salton Sea Area (Acres)	Evaporation Rate (feet/yr)	Evaporative Losses (AF/yr)	Ocean Salinity (mg/L TDS)	River Water Salinity (mg/L TDS)	Target Salinity For The Salton Sea	Difference between Salton Sea and Ocean	
230000	7	1610000	35000	3500	45000	10000	mg/L
	84	<=(inches per year)	43.17	4.32	55.51	12.33	Tonnes/AF

Conversion Factors
1233482 Liters/AF
0.00123348 mg/L to Tonnes/AF

Average Depth of the Salton Sea (ft)	Surface Area of the Salton Sea (acres)	Volume of the Salton Sea (AF)
35	230,000	8,050,000

Sea-to-Sea Evaluation

Volume of River Inflow	Sum of Ocean Input (AF/Yr)	Sum of Salton Sea Output (AF/Yr)	Ocean Input for Stability (AF)	Salt Load Rivers (tonnes)	Salt Load Ocean Stability (tonnes)	Total Salt Input (Tonnes)	Ocean/Salton Sea Exchange for salt balance (AF)
1200000	2265000	1855000	410000	5180624	17700467	22881091	1855000
1150000	2472500	2012500	460000	4964765	19859060	24823825	2012500
1100000	2680000	2170000	510000	4748906	22017654	26766559	2170000
1050000	2887500	2327500	560000	4533046	24176247	28709294	2327500
1000000	3095000	2485000	610000	4317187	26334841	30652028	2485000
950000	3302500	2642500	660000	4101328	28493434	32594762	2642500
900000	3510000	2800000	710000	3885468	30652028	34537496	2800000
850000	3717500	2957500	760000	3669609	32810621	36480230	2957500
800000	3925000	3115000	810000	3453750	34969215	38422964	3115000
750000	4132500	3272500	860000	3237890	37127808	40365698	3272500
700000	4340000	3430000	910000	3022031	39286402	42308433	3430000
650000	4547500	3587500	960000	2806172	41444995	44251167	3587500
600000	4755000	3745000	1010000	2590312	43603589	46193901	3745000
550000	4962500	3902500	1060000	2374453	45762182	48136635	3902500

Salt Balance for River by Evaporation Only

River Inflow Volume	Salt in River Water Runoff tonnes	Salton Sea equivalents AF	Evap rate AF/mi^2 AF	Area Needed to Remove Salt Assoc with River Water Using Salton Sea Evaporation Square Miles	Acres
1,200,000	5,180,624	93,333	4,480	20.83	13333
1,150,000	4,964,765	89,444	4,480	19.97	12778
1,100,000	4,748,906	85,556	4,480	19.10	12222
1,050,000	4,533,046	81,667	4,480	18.23	11667
1,000,000	4,317,187	77,778	4,480	17.36	11111
950,000	4,101,328	73,889	4,480	16.49	10556
900,000	3,885,468	70,000	4,480	15.63	10000
850,000	3,669,609	66,111	4,480	14.76	9444
800,000	3,453,750	62,222	4,480	13.89	8889
750,000	3,237,890	58,333	4,480	13.02	8333
700,000	3,022,031	54,444	4,480	12.15	7778
650,000	2,806,172	50,556	4,480	11.28	7222
600,000	2,590,312	46,667	4,480	10.42	6667
550,000	2,374,453	42,778	4,480	9.55	6111